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TABLE 2

	λ IN A. U.	INT.	$\frac{10^8}{\lambda}$	FREQUENCY DIFFERENCE		λ IN A. U.	INT.	$\frac{10^8}{\lambda}$	FREQUENCY DIFFERENCE
	6167.4	8	16214.29	1038.41		4366.5	4	22901.64	1033.25
	5796.2	5	17252.70			4178.0	6	23934.89	
	5811.7	3	17206.67	1034.35		5907.4	2	16927.92	2017.57
	5482.15	6	18241.02			5278.3	1	18945.49	

A preliminary attempt at a Rydberg formula gives the following results for the first line of the three classes of triplets:

$$\text{Principal series,} \qquad n = 44349.0 - \frac{109675}{(m + 1.0855)^2}$$

$$\text{First subordinate series,} \qquad n = 25236.8 - \frac{109675}{(m + .8062)^2}$$

$$\text{Second subordinate series,} \qquad n = 25153.0 - \frac{109675}{(m + .6196)^2}$$

It is very probable that further investigation will modify these formulae, but the existence of the triplets seems well established, and the fact that alternate elements in the chemical table show a spectroscopic relation is suggestive for further work along this line.

[1] Runge, C., and Precht, J., *Phil. Mag., London*, **5**, 1903, (476).

[2] Ives, H. E., and Stuhlmann, O., *Physic. Rev., Ithaca, N. Y.*, (Ser. 2), **5**, 1915, (368).

[3] Kayser, H., *Handbuch der Spectroscopie*, vol. 6, p. 325.

THE MEASUREMENT OF SMALL ANGLES BY DISPLACEMENT INTERFEROMETRY

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Parallel rays retracing their path.—The following method was devised with a view to the micrometric measurement of angles. It is to be used below in connection with an electrometer for reading microvolts. An interference method of a different kind for measuring small angles was developed some time since and used at length in connection with the deviation of the horizontal pendulum.[2] Again the electrometer was treated in different ways[3] by the aid of the displacement interferometer. The present method, however, will differ from all of these. In figure 1, *L* is a horizontal beam of white light from a collimator. After passing through the auxiliary clear plate P (to be used preliminarily for parallelizing the mirrors of the system in a way presently to be shown), the beam is reflected at a and b by the half silver plates H_1 and H_2 respectively to the wide opaque mirror m. The rays now retrace their paths or nearly so to be in turn transmitted at a and b by the half silvers H_1 and H_2. These transmitted pencils similarly impinge on the opaque mirror M and the half silver H_3 at c and d respectively, and pass thence (the ray from c being transmitted) into the telescope at T. The direct vision grating-prism g may be swivelled in place or removed, at pleasure.

To bring the system of four mirrors into complete parallelism is here of considerable importance if the spectrum fringes or the residual phenomenon are to be adequately large for measurement. The presence of the common mirror m, however suggests the procedure. When the clear plate P is in place, the rays ae and bf on returning are also again reflected at a and b toward L and may be clearly seen in a telescope[4] at p. Hence if m is the standard plane and nearly vertical, the mirrors H_1 and H_2 will be parallel when the slit images seen at p coincide horizontally and vertically, while H_1, H_2 and m will have their common normal plane in the diagram. In the same way the mirrors M and H_3 may be parallelized with their common normal plane in the diagram. If the distances ac and bd, ab and cd have previously been made nearly equal and the angles approximately 90°, the fringes will usually be found on moving the micrometer screw normal to H_3.

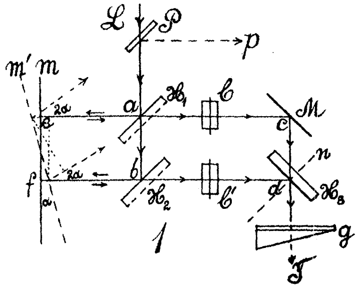

FIG. 1.

As the mirrors are thick glass plates it is preferable that the half silvered sides of H_1 and H_2 be toward L, and the half silvered side of H_3 toward M. In this case each ray passes the plates twice, as indicated in figure 1. With ordinary plate glass the fringes when found are still apt to be small. They are then to be enlarged and centered, by compensator of clear glass C and C', in the two rays respectively, rotated in opposite directions around a horizontal axis until the center of ellipses is in the field of the spectroscope. It may be necessary to actuate the micrometer screw at *d* to complete the adjustment.

When the ellipses are centered, the direct vision spectroscope *g* removed, and the slit widened or removed, the residual or achromatic fringes appear in sight and are ready for use. These are always strong. The spectrum fringes are apt to be less so, since the parts of the ray *L* pass through two half silvered surfaces H_1H_2 or H_1H_3 in succession.[5] The spectrum fringes are sharp when the slit is fine. If the white residual fringes are too dazzling a single or two half silvers may be placed before the objective of the telescope with advantage. Two plates with their half silvered sides in contact and held so by a steel clip, are excellent for this purpose while they are at the same time protected from sulphur corrosion. This in fact is the best method of preserving silver mirrors (in pairs) when not in use.

When the spectra are in coincidence and the fringes sharp, the mirror *m* may be rotated around a vertical axis at *A* into some position, *m'*. In such a case the two spectra will move through the field of the telescope at *T*, but their coincidence will not be destroyed. The *D* lines, for instance, will continue to be superposed throughout. Considerable path difference is however introduced in this way and hence the fringes will march through the spectrum at an enormously more rapid rate. The following data may be given, where α is the angle of rotation of the mirror *m* and *N* the reading of the micrometer at H_3 (screw in the normal *dn*) necessary to bring the center of ellipses back to the sodium lines. In both cases the centers were out of the field (above or below), so that horizontal fringes were made the criterion for adjustment. This method is somewhat rough, but adequate for the present purposes.

1. Fine thin fringes. Relatively large differential glass path. Distance *ab*, figure 1, $2R = 21$ cm. Thickness of glass plates (half silvers) $e = .70$ cm.

$\alpha =$	0°	.05°	.20°	.30°	.40°	.50°	.60°
$N \times 10^3 =$	23	30	128	162	215	258	299 cm.

This is curve *a* in figure 2. From it the mean rate

$$\frac{\Delta N}{\Delta \alpha} = .47 \text{ cm/degree, or } 27 \text{ cm/radian}$$

may be found.

2. Coarse large fringes. Smaller differential glass path.

$\alpha =$	0°	.1°	.2°	.3°	.4°	.5°	.6°	.7°	.8°	.9°	1.0°
$N \times 10^3 =$	−25	+29	84	134	176	217	265	323	365	420	467 cm.

This is the curve given (with double ordinates for distinction), in curve *b*, figure 2, and in figure 3. Besides this the datum $\alpha = -.6°$, $N = -.320$ cm was obtained. In figure 3 the mean rate is

$$\frac{\Delta N}{\Delta \alpha} = .465 \text{ cm/degree, or } 26.6 \text{ cm/radian,}$$

agreeing with the preceding as closely as may be expected. We may thus estimate $\Delta N = 27 \times 10^{-6}$ of displacement at the micrometer at H_3 per micro-radian of turn α at the mirror m, which amounts to a little less than one interference ring per microradian (about one-fifth second of arc) of turn. The theory will be given later. With regard to the application to the electrometer we may come to the following conclusion. A good instrument of the quadrant or similar type should give about a radian of deflection per volt, or a microradian per microvolt. In the present interferometer the microradian is about equivalent to the passage of one interference fringe. Hence one fringe per microvolt is about the order of sensitiveness to be expected.

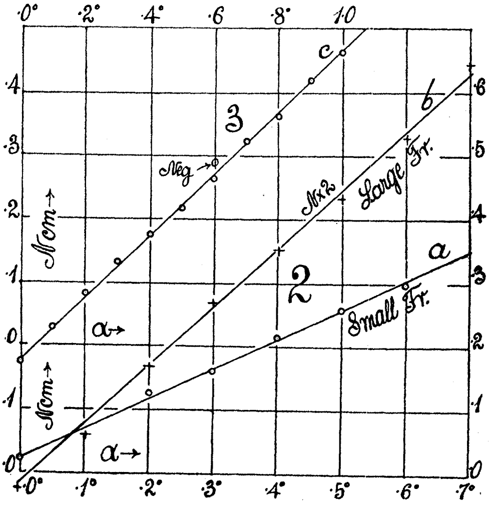

FIG. 2 AND 3.

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[1] This contribution is a note from a Report to the Carnegie Institution of Washington.

[2] *Washington, Carnegie Inst., Pub.*, No. 229, 1915, (¶ 10 et seq.)

[3] *Ibid.*, (¶ 67 et seq.)

[4] The return rays may also be projected in a screen near the objective of the properly focussed collimator and the sharp images put in contact.

[5] If α is the refraction of light transmitted and $1 - \alpha$ reflected, the fraction of the original light, L, reaching the telescope T will be $2\alpha^2(1 - \alpha)^2$. This is a maximum if $\alpha = \frac{1}{2}$. Thus the illumination is reduced to $\frac{1}{8}$.